Summary

There is a lot of information in this booklet, and, if you have not had much exposure in some of the areas covered you may find it overwhelming at the first reading. Please keep this on hand as you can refer to it in instances where you need to review material or apply it to your responsibilities at your station's control point. When you understand the basic information presented, you will be in a better position to know what both your station and the Federal Communications Commission expects from you as a Control Operator. Your performance will be judged based on your ability to carry out your responsibilities both in the areas set forth here as well as other areas relating to the Master Control Room.

You will find that both your Station Manager and Chief Engineer will be more than glad to work with you in trying to identify areas in which you are having trouble understanding or otherwise having difficulty performing your assigned duties. They will do their best to assist you in getting your knowledge and skills brought to your station's standards so that both you and your station can benefit from your training.

Appendix A

"Some Questions and Answers About Television"

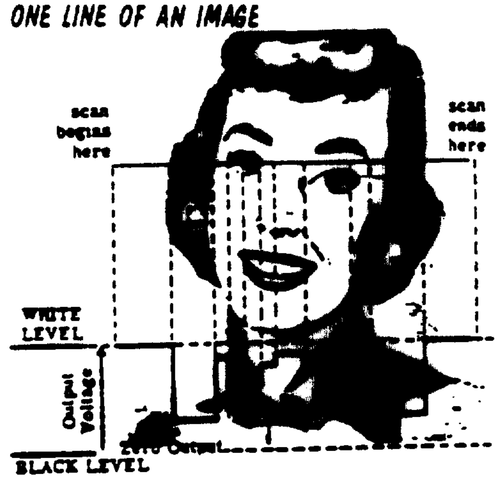
SOME QUESTIONS AND ANSWERS ABOUT TELEVISION

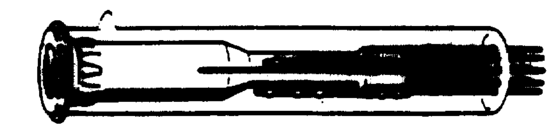
GENERATING VIDEO SIGNALS

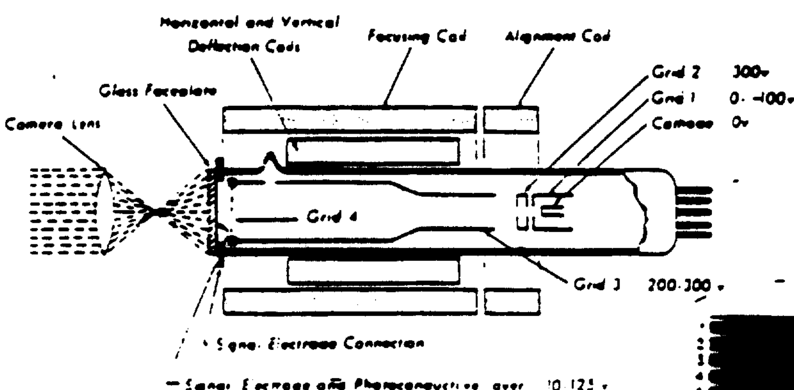
1. How does a television camera work?

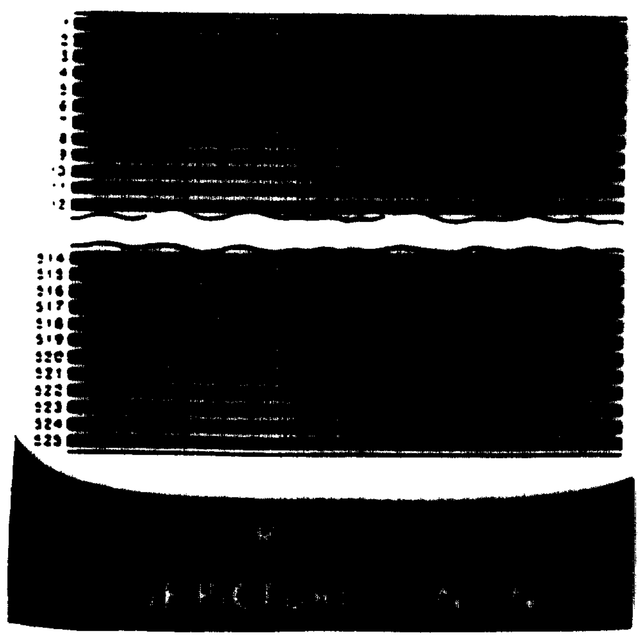
A. In a monochrome camera, the lens forms an optical image on the photoconductive layer of the faceplate of an electron tube. Inside the tube a sharply focused beam of electrons is driven back and forth in a scanning action, converting variations in light and shadow in the optical image into variations in the electrical output of the tube — i.e., video signals (see number . Color television cameras have three tubes to provide red, green, and blue signal outputs, and sometimes a fourth tube that produces a luminance signal.

THE VIDEO SIGNAL PRODUCED BY SCANNING ONE LINE OF AN IMAGE



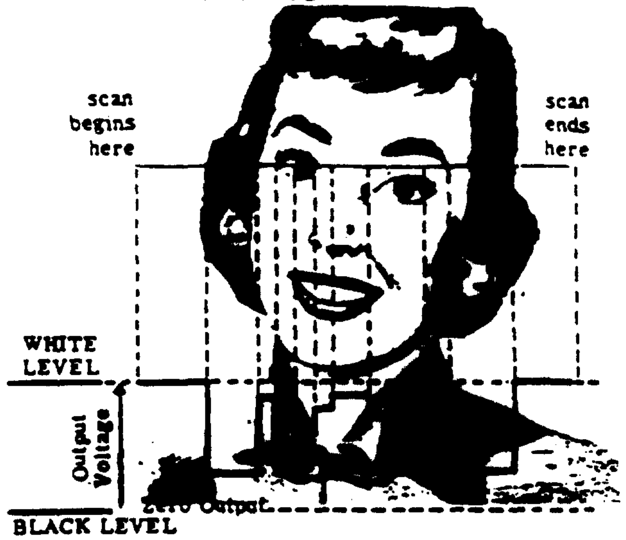


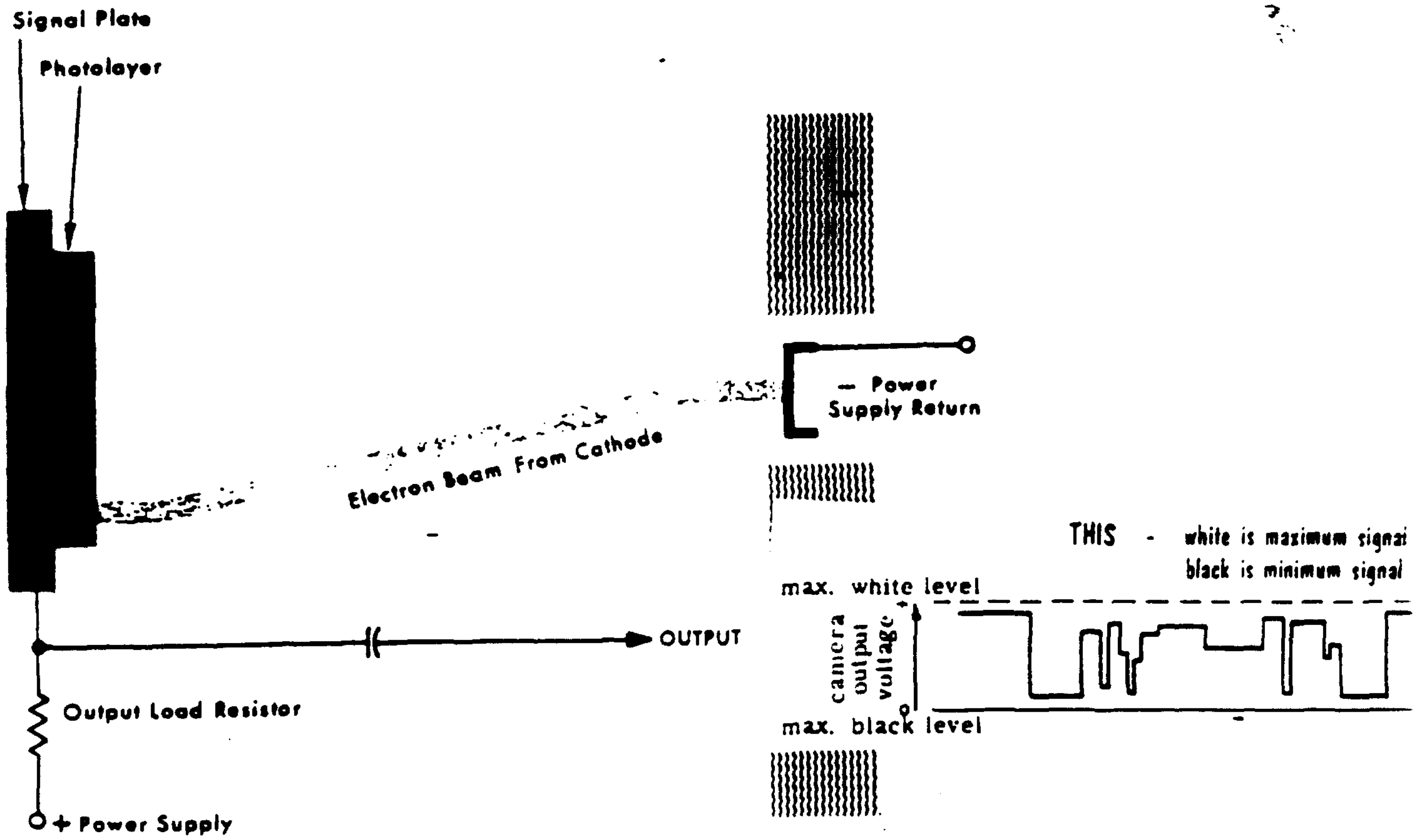




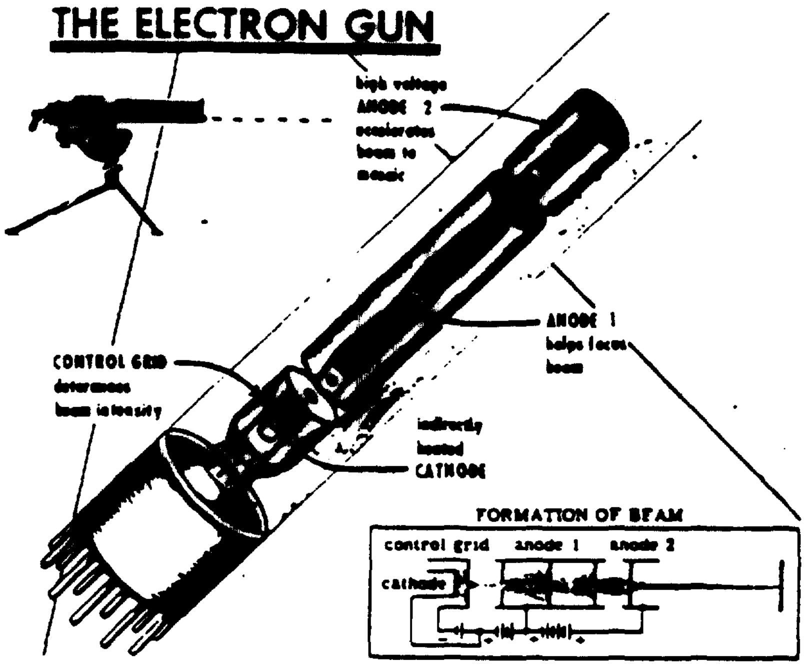
A. The electrical output of a television camera tube is known as a video signal. It consists of variations (with time) in electrical voltage corresponding to variations (in space) in the tonal scale from black to white in the optical images formed by the lens on the faceplate of the camera tube. The video signal at the camera output falls to its lowest level as the scanning beam traverses picture shadow areas and rises to maximum in bright highlight areas.

THE VIDEO SIGNAL PRODUCED BY SCANNING ONE LINE OF AN IMAGE



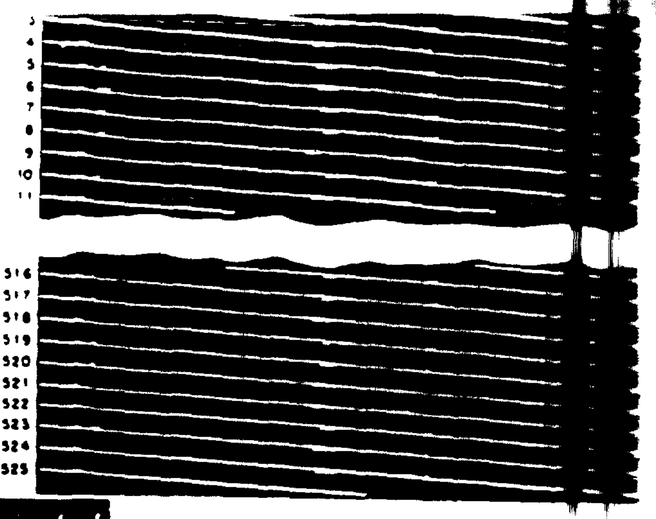


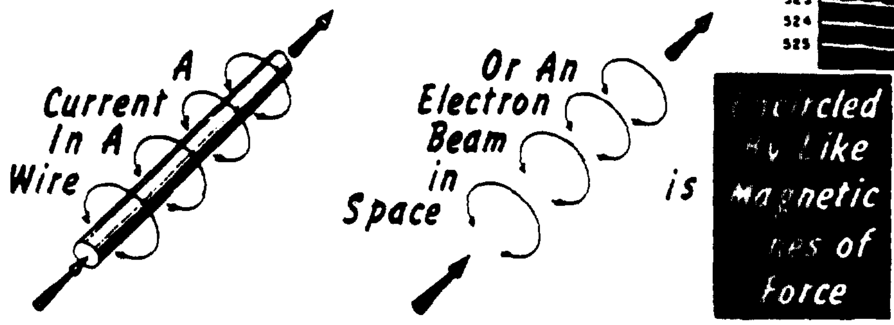
A. At the base of the camera tube there is an electron gun in which a heated element gives off electrons. These tiny electrical charges are focused by an electrooptical lens into a fine spot at the faceplate. An electrooptical lens uses electrostatic and/or electromagnetic fields to cause the electron beam to diverge or converge in a manner analogous to the effect of an optical lens on light rays.

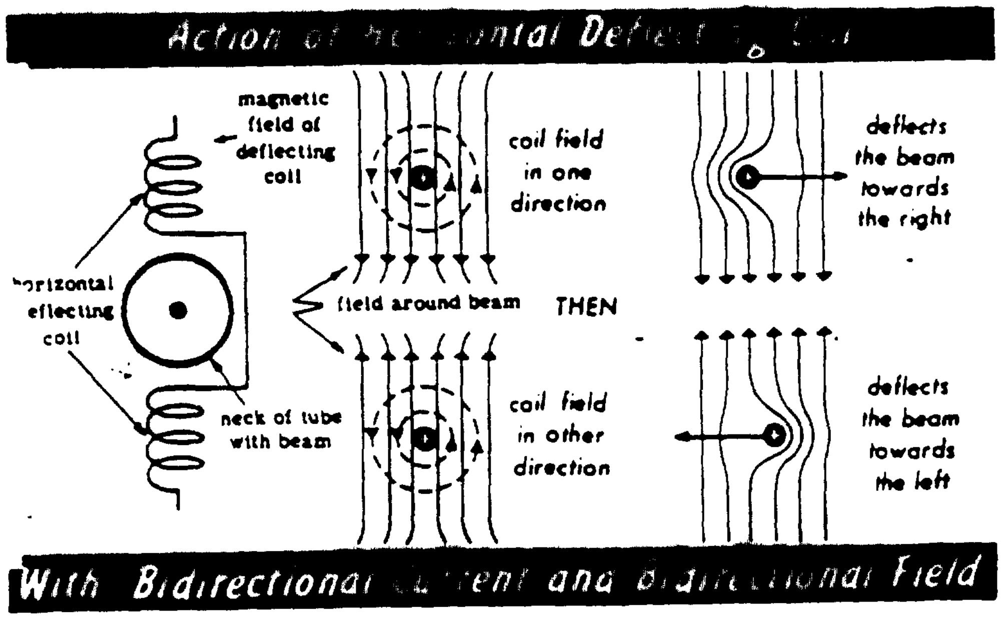


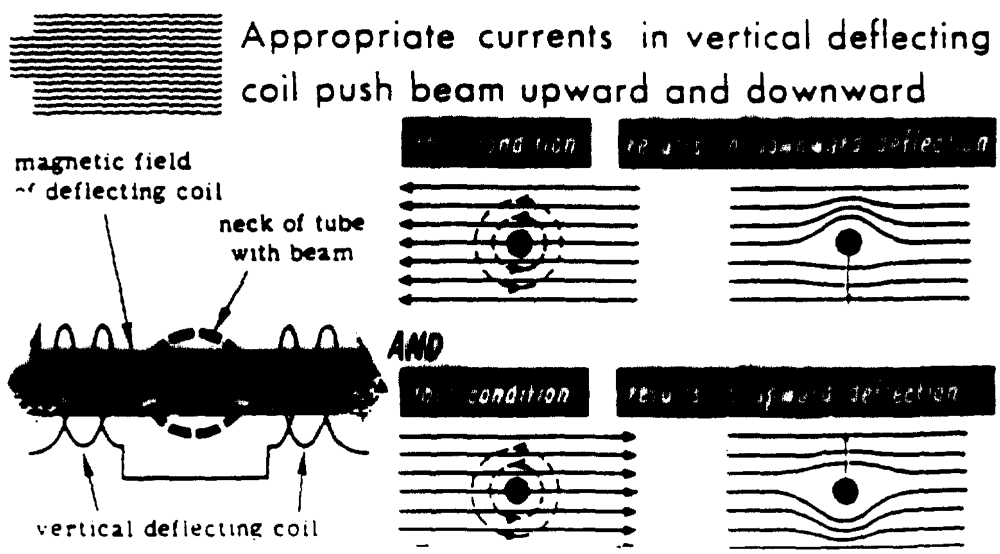
4. How does the scanning action take place?

A. An electron beam can be deflected from its normal path by using magnetic fields. Surrounding the camera tube are coils of wire. Electrical currents in these coils produce magnetic fields by which the electron beam is driven back and forth (horizontally) and up and down (vertically). By properly timing and synchronizing the electrical pulses applied to the coils, the electron beam can be made to scan or trace out a rectangular pattern called a raster.







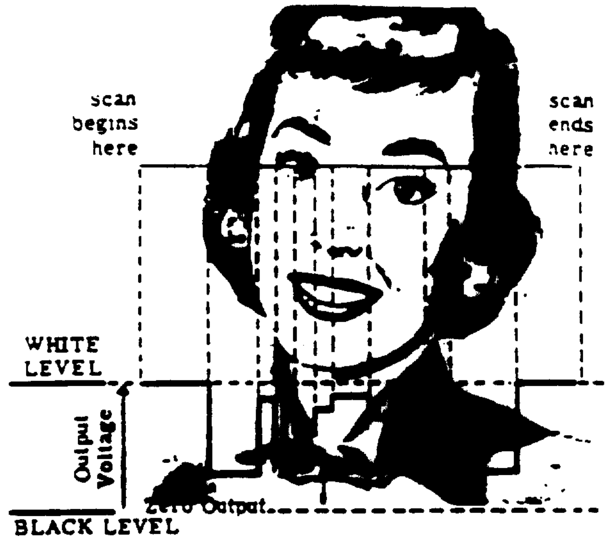


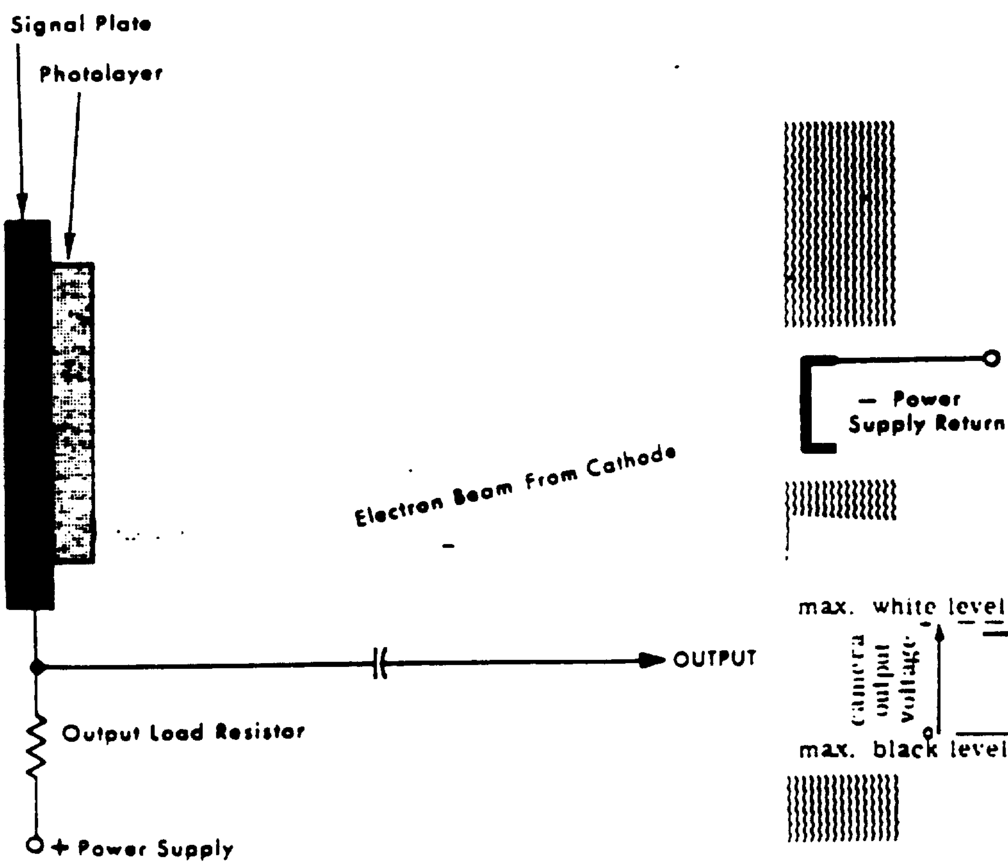
05755

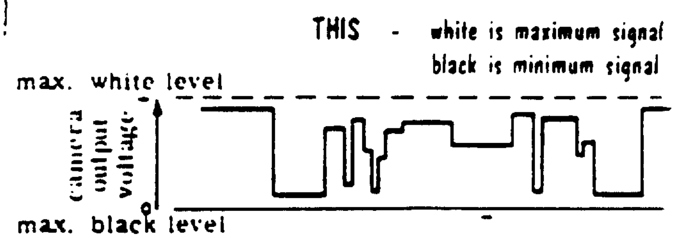
Into video signals?

A. There are several types of television camera tubes with different characteristics. The simplest type of tube is the vidicon, consisting mainly of an electron gun at the base, and a faceplate at the front end, coated on the inner surface with a transparent signal electrode and a photoconductive layer. When an optical image is projected onto this layer, an electrical charge pattern is created. As the electron beam scans the rear side of the layer, electrons are taken from the beam in relation to the charge pattern, and flow out of the signal electrode as a tiny electrical current. This current forms the video signal.

THE VIDEO SIGNAL PRODUCED BY SCANNING ONE LINE OF AN IMAGE





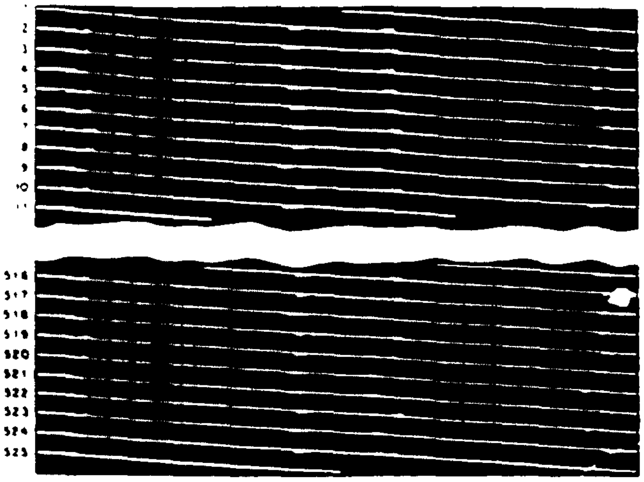


TELEVISION SCANNING STANDARDS

6. How long does it take for the electron beam to scan the optical image?

A. In the North American television system there are 30 complete frames per second, a frame being made up of two interlaced fields. In each frame there are 525 horizontal scanning lines. The scanning beam first traces out all of the odd-numbered lines starting at the top of the picture; then the beam is driven back to the top of the picture to trace out the even-numbered lines. The time required to scan one horizontal line, including retrace, is 63.5 microseconds, and a complete frame is scanned in 1/30 second.

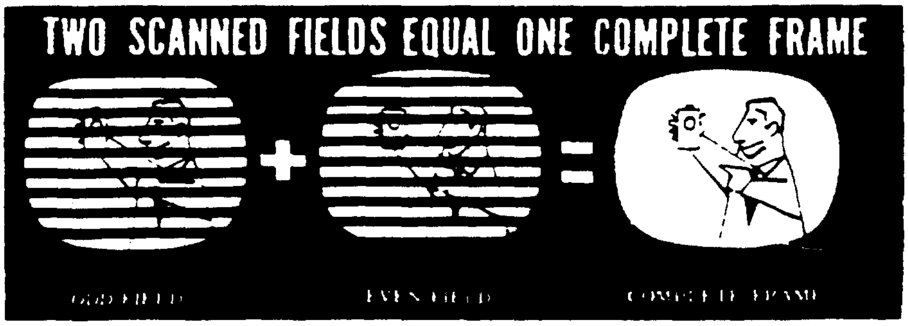
The Interlaced Scanning Pattern



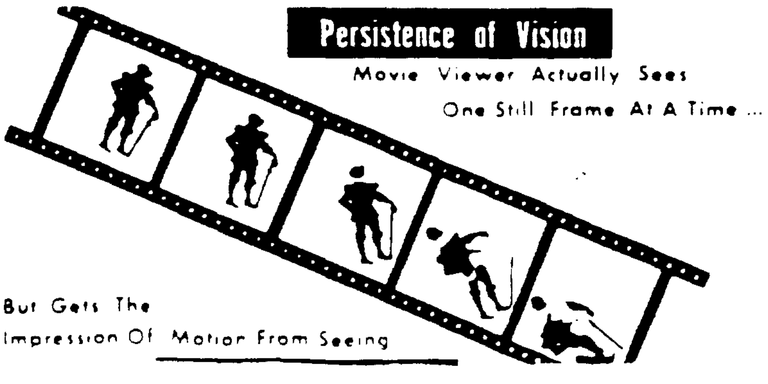
THE TWO FIELDS INTERLACED

Note: Instantaneous return from bottom to top of mosaic is assumed here.

A complete picture is seen *only* when two consecutive fields appear, interlaced, on the picture tube screen. When two consecutive fields have been transmitted, a *frame* has been transmitted. The presentation of the individual field content in terms of rows of picture information is illustrated below.

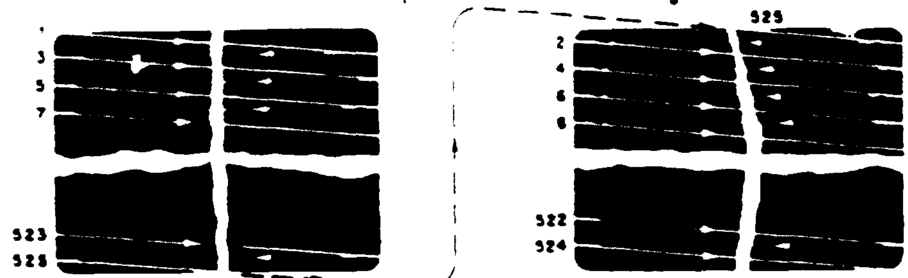


To scan a complete field consumes 1/60 second. This is true in the camera tube and at the receiver picture tube. Because a frame consists of two fields, the total time lapse for a frame is $2 \times 1/60$ second, or 1/30 second. These time intervals are very important for several reasons which are discussed later. In the meantime we should answer a question which no doubt has risen in your mind. If each field is transmitted separately how can the viewer see a complete picture corresponding to a frame? The answer is found in a characteristic of the human eye known as *persistence of vision*. The brain "memorizes" the first field, and because the two consecutive fields follow each other in such rapid sequence, the brain sees a complete frame or picture instead of two separate fields.



05756

Each Field Is Made Up Of 262.5 Scanning Lines



ODD FIELD

The picture content of the odd-numbered rows is scanned

EVEN FIELD

then the picture content of the even-numbered rows is scanned.

ODD FIELD EVEN FIELD COMPLETE FRAME

1. *Interlaced Scanning.* All odd-numbered lines are scanned as a group (a field). then all even-numbered lines. The first and last lines of each field are only half-rows: interlacing begins here. The complete interlaced scan of two consecutive fields (the first held in the viewers eye by persistance of vision) produces an intelligible picture.

8. Why wasn't the frame rate increased to 60 per second, instead of having 30 frames with two fields?

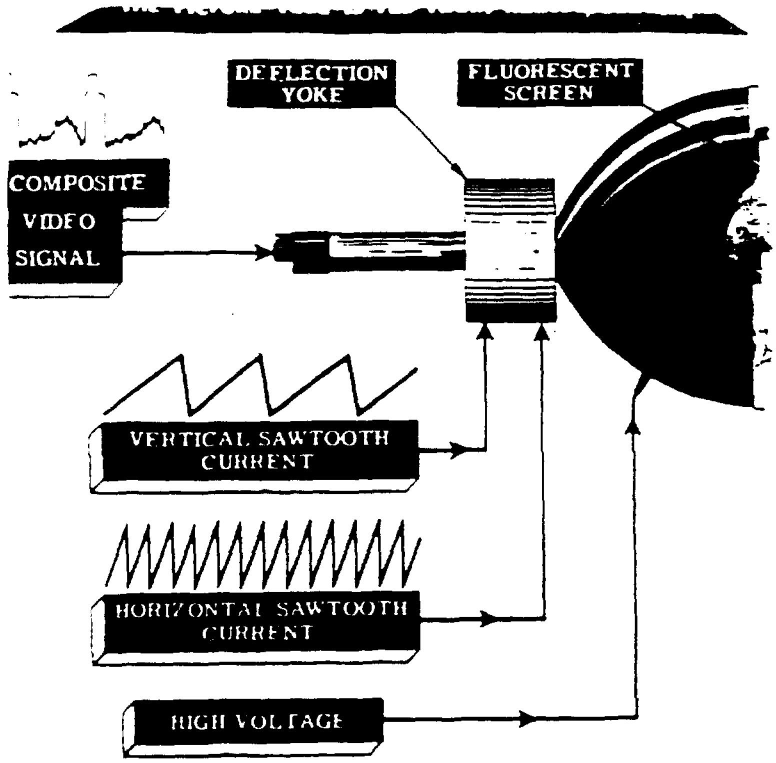
A. Increasing the frame rate to 60 per second while at the same time retaining the detail-producing ability of the system would require doubling of the picture frequency bandwidth to 8.5 MHz.

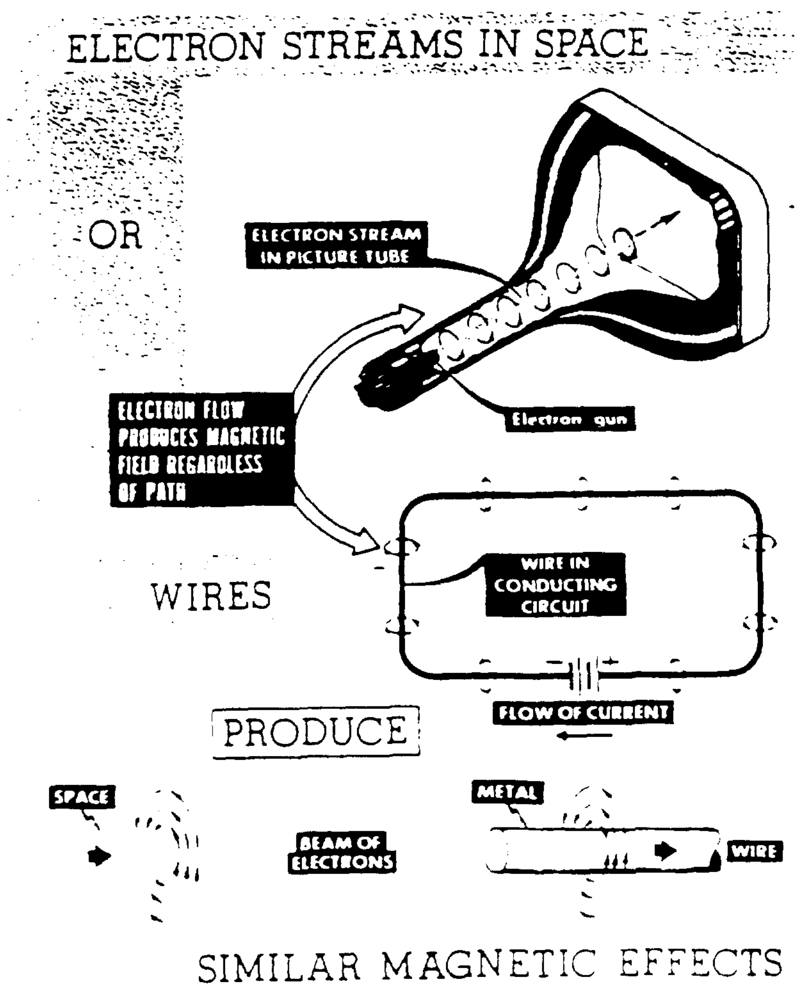
9. How can a television frame be divided into two fields?

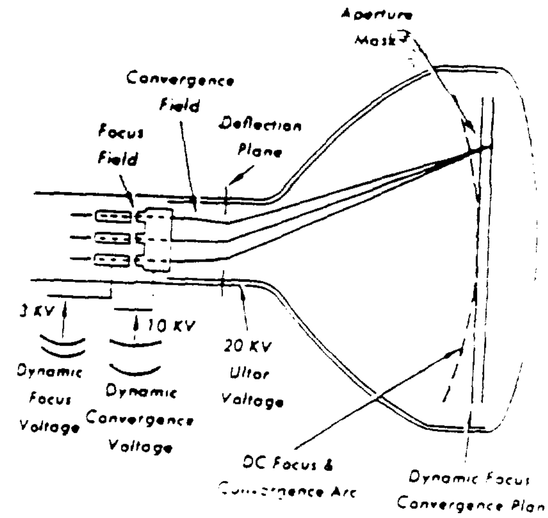
A. Each television frame consists of 525 horizontal scanning lines divided equally between two fields. The first field, of the 262½ odd-numbered lines, is designed to finish at the bottom and halfway across the picture. The scanning beam is then returned to the top center of the picture so that the even-numbered lines of the second field are displaced halfway between the lines of the first field.

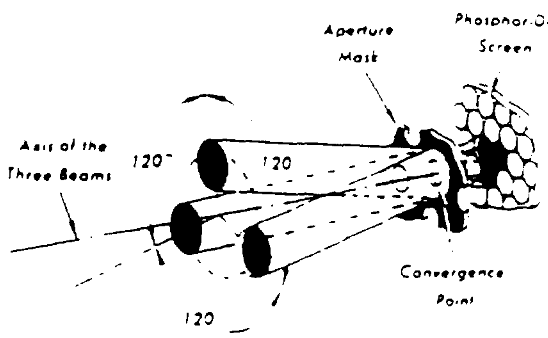
10. How does the television receiver work?

A. The picture display tube in a monochrome receiver converts incoming video signal variations into variations in light and shadow to recreate the optical images from the television camera. The picture tube contains an electron gun at the base, while the inner surface of the tube face is coated with a phosphor layer. This layer gives off light when the scanning beam strikes it. The video signals picked up by the antenna are amplified, processed, and then applied to the electron gun, causing the intensity of the scanning beam to vary as the lines and fields are being traced out. Synchronizing pulses transmitted with the picture signals keep the scanning beam in the receiver in step with the beam that is tracing out the raster in the camera. In a color receiver, the picture display tube contains three electron guns for the red, green, and blue components of the color pictures, and instead of a single phosphor layer, the inner surface of the tube face is coated with large numbers of tiny phosphor dots giving off red, green, and blue light. A thin metal mask mounted close to the layer of color phosphors makes certain that the electron beams from the three guns strike only the corresponding phosphor dots. Audio signals transmitted along with the picture signals are separated in the receiver and applied to a loudspeaker.









Relationship between electron beams, aperture mask and phosphor screen in the color picture tube

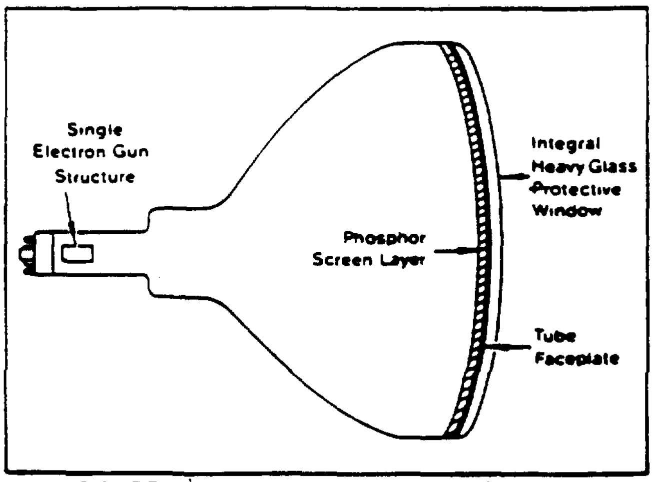


FIGURE 1 Monochrome Picture Tube Diagram

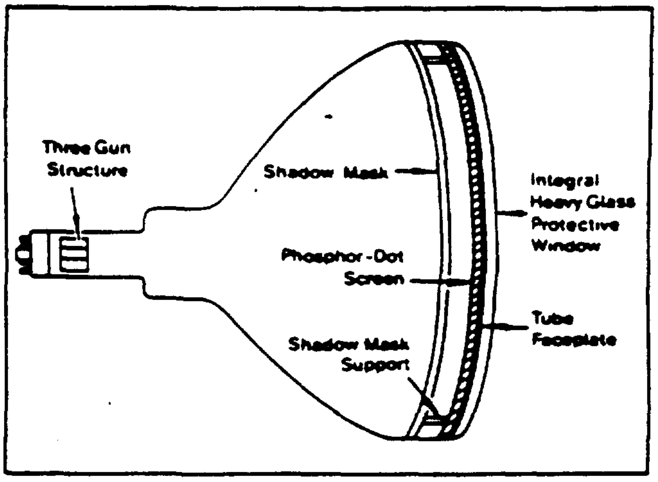


FIGURE 2 Color Picture Tube Diagram

05758

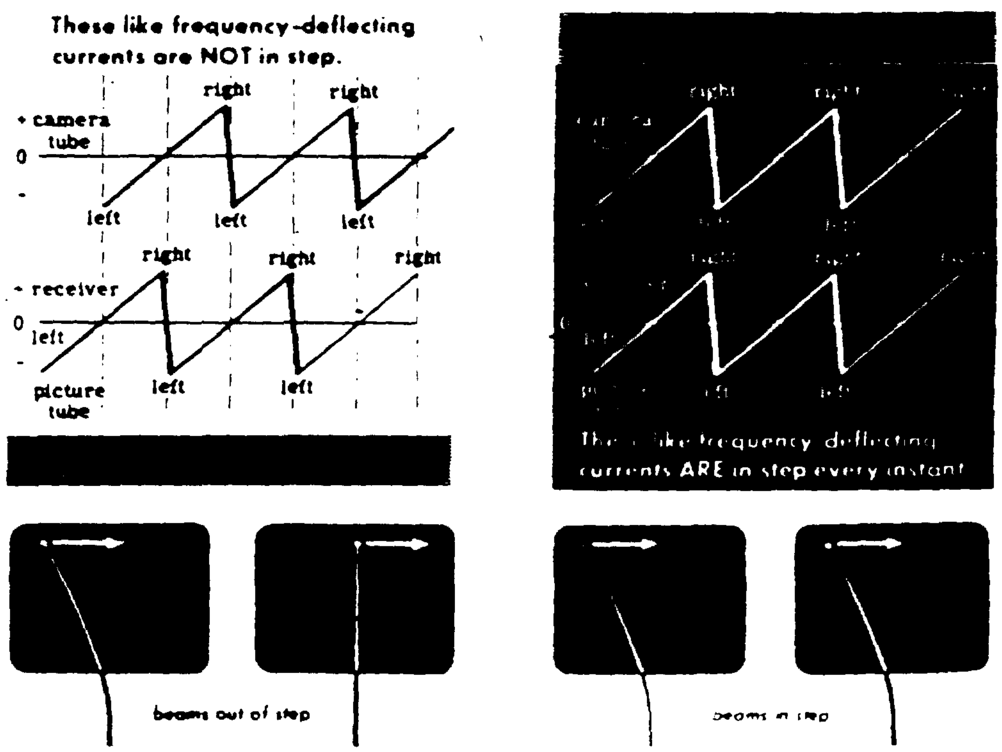
185

ning beams?

A. The pulses from the synchronizing generator have different shapes and widths. At the beginning of every horizontal scanning line there is a square pulse about 5 microseconds in duration. This pulse triggers the horizontal deflection oscillator in the receiver and causes the scanning beam to sweep back and forth across the phosphor layer at the rate of 15,750 times per second. At the end of each field scan — that is, 60 times per second — there is a vertical synchronizing pulse with a width equal to three horizontal line periods. During the vertical blanking interval of 20 horizontal line periods, the action of the scanning beam is suppressed by a blanking pulse while the beam is being returned to the top of the picture to begin the tracing of the next field.

Adding the Sync Pulses to the Video Signal

Reconstruction of a television scene on the screen of a **monitor or receiver picture tube requires that the electron** beam in this tube **describes exactly the same horizontal and vertical** motions as does the **electron beam in the camera tube. It is not enough for the** two beams to move **under the influence of deflecting currents of identical** frequency; the current **variations must be perfectly in step with each other.**



BEAM MOTIONS IN CAMERA AND PICTURE TUBES

The two beams must change direction at the same instant, **and must reach their minimum and maximum values** in step with **each other. If the two beams do not move in synchronism** an unintelligible picture **will be reconstructed. To assure perfect** reconstruction of the televised scene, the vacuum tube generators that supply the horizontal and vertical deflection voltages to the deflecting coils in the camera and those in the receiver which produce the deflection voltages for the deflecting coils of the picture tube, are synchronized by voltage pulses [illegible] from the same source— the pulse generator at the transmitter.

12. **What are synchronizing signals?**

A. At the television station where programs originate there is an electronic device called a synchronizing generator. This device puts out a continuous stream of accurately timed and shaped pulses that control the electron beams in the station's cameras. These pulses are then added to the video signals from the cameras for transmission to the television audience. In the receivers tuned to this station the pulses are separated from the picture portion of the incoming signals and control the action of the scanning beams in the picture tubes.

Synchronization

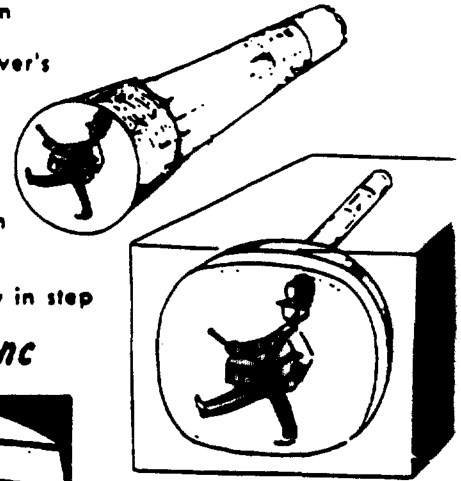
It is essential that the Transmitter's Camera Tube Scanning Beam

and the Receiver's

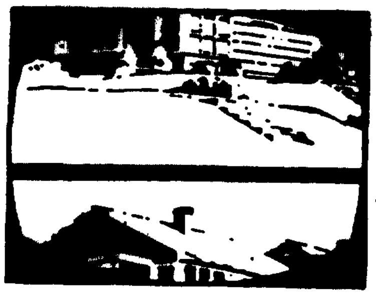
Picture Tube

Scanning Beam

move precisely in step

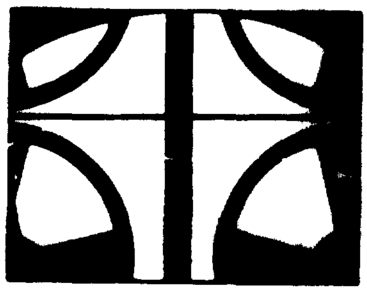


Vertical Sync



Horizontal Sync

LOSS OF SYNC

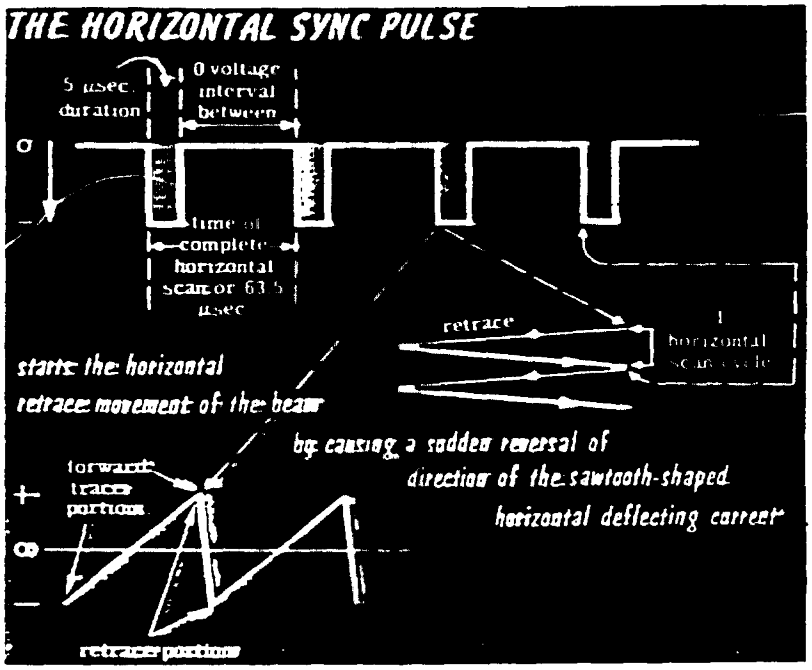


Horizontal and Vertical Sync

the scanning beam in the picture tube must move precisely in step with the scanning beam in the camera tube. The sweep oscillators in the receiver develop sweep voltages that can move the receiver picture-tube electron beam at *approximately* the correct rate in each direction. But approximateiy is not good enough! The beams in the receiver picture tube and in the transmitter camera tube must move *exactly* in step. To achieve this, the picture tube beam movement is placed under the control of the transmitting scanning system. The control is maintained by triggering or synchronizing pulses which are received from the transmitter. One is the *horizontal synchronizing* or *sync pulse;* the other is the *vertical sync pulse*. There are also *equalizing pulses*. They are all part of the modulation that is superimposed on the picture carrier at the transmitter and they appear in the signal output of the video detector.

Adding the Horizontal Sync Pulse

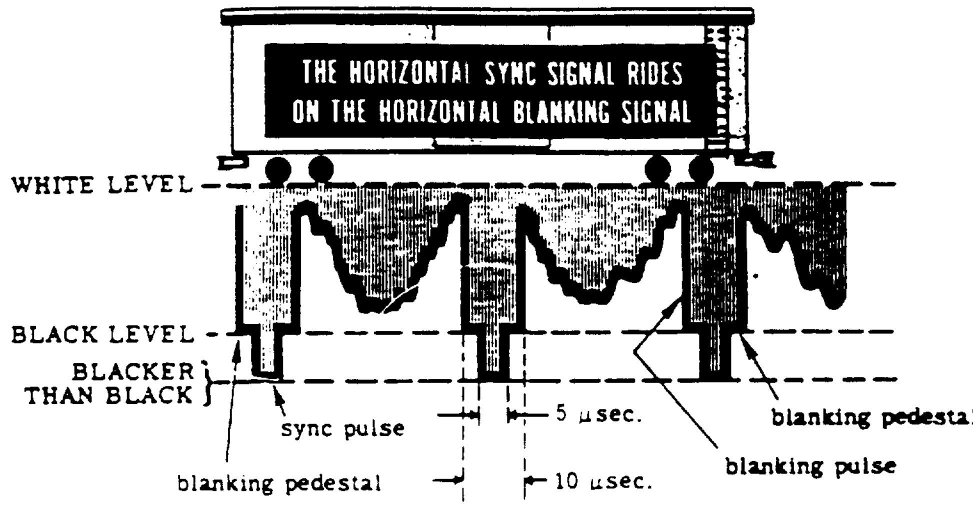
Sync pulses are of two kinds: horizontal and vertical. At this time we shall discuss only the synchronizing pulse that is related to the horizontal movement of the beam.



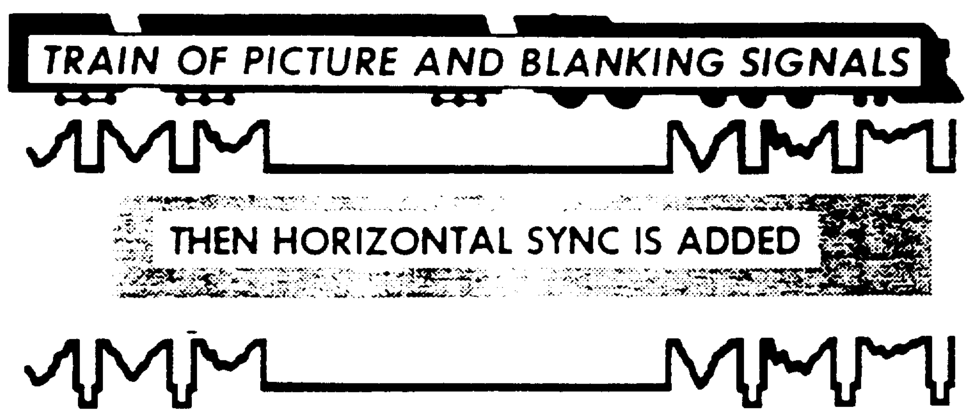
The horizontal sync pulse is very narrow; it lasts for only 5 microseconds. Its polarity is the same as that of the horizontal blanking pulse, for as will be seen shortly, the sync pulse rides on the blanking pulse enabling its separation from the picture signal in the receiver. The pulse is timed to appear coincidentally with the arrival of the beam at the end of its horizontal excursion towards the right [illegible] trigger the horizontal deflection generating system to initiate the retrace [illegible] the horizontal scanning cycle. In other words the horizontal sync [illegible] appears at the end of each horizontal scan. In this way the electron beam [illegible] receiver picture tube is positioned at the proper point on the screen [illegible] the picture information being developed in the camera [illegible] in the identical position on the mosaic or target [illegible] emphasize that the destination of the horizontal sync pulse [illegible] to the receiver as a part of the picture signal is the horizontal deflecting current generator system.

Adding the Horizontal Sync Pulse (contd.)

Each horizontal sync pulse is timed to appear just slightly after the start of the 10-microsecond horizontal blanking pulse which appears at the end of each horizontal scan. Having a duration of only 5 microseconds, the sync pulse ends before the blanking pulse. Therefore, the sync pulse occurs within the duration period of the blanking pulse. By making the peak

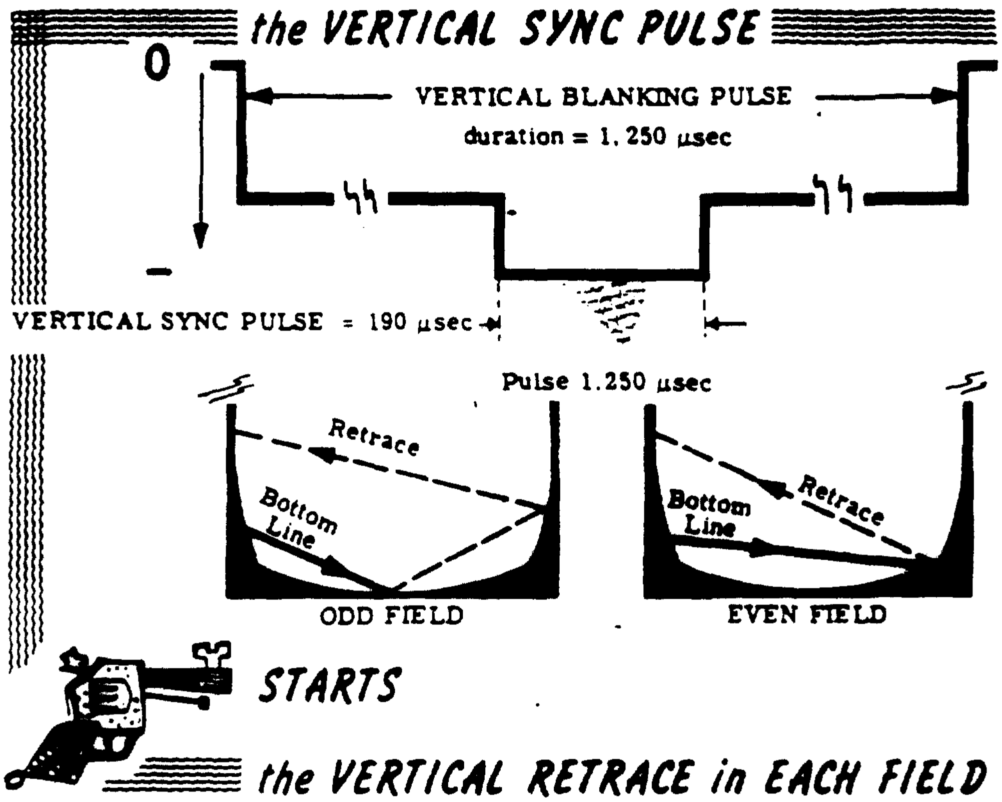


amplitude of the sync pulse greater than that of the blanking pulse, the sync pulse extends beyond the blanking pulse pedestal when the two are seen together. This makes it possible to "clip" the sync pulse off the blanking pulse pedestal in the receiver and to use it as a timing signal. Also, because the sync pulse extends beyond the black level set by the blanking signal pedestal height, the sync pulse signal is said to be located in the "blacker than black" region of the picture signal.



Adding the Vertical Sync Pulse

It is not enough that the receiver picture tube beam move from side to side in synchronism with the camera tube beam. The two beams must also move in step in the vertical direction. To make this happen is the function of the vertical sync pulse, which, like its horizontal counterpart, is used in the transmitter, and is received as part of the picture signal. In both the transmitter and the receiver the vertical sync pulse is applied to the vertical deflection generator where it triggers the sudden reversal of direction of the vertical deflection current. In so doing it starts the scanning beam moving upward at a particular moment in relation to the overall scanning



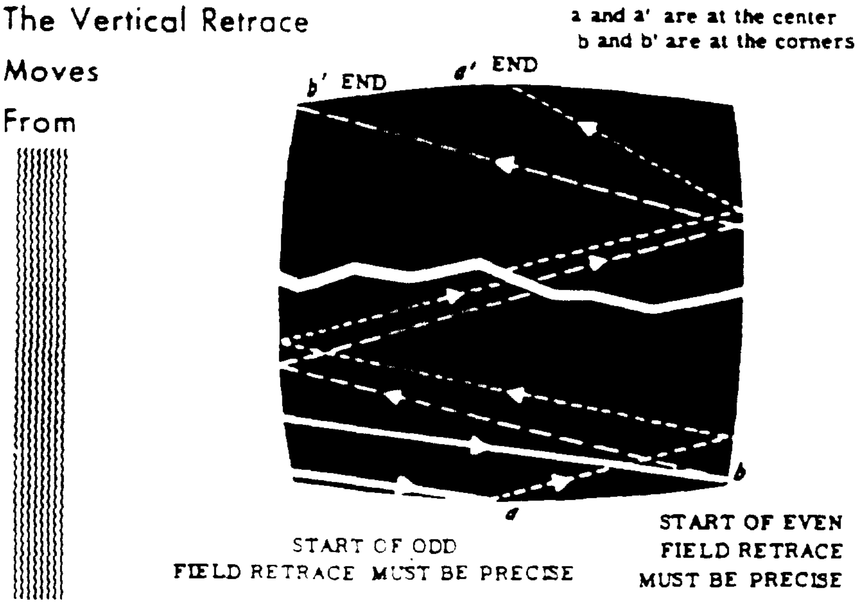
The vertical retrace action of the scanning beam occurs once in each field; when the beam, having scanned the bottom horizontal line, is ready to move to the top of the scanned surface and begin scanning the next field. The vertical sync pulse appears every 1/60 sec or 60 times per second. The pulse interval is 190 microseconds. This makes it a long-duration pulse in comparison with the 5-microsecond horizontal pulse.

The beam moves upward, but not straight up; it zig-zags from side to side because of the action of the horizontal deflecting field which is ever present in both the camera tube and in the receiver picture tube. This movement must occur if the beam is to start scanning horizontally the moment the vertical retrace is completed. In this connection, each beam must be at its correct location—the camera tube beam ready to start the development of the picture information for transmission and the receiver tube beam ready to reconstruct the picture. For both the camera tube and the receiver picture tube, the moment *when* retrace begins in each field is extremely important. Each must begin at one precise instant if correct interlace of the two fields is to be accomplished. For this reason, and also to make certain that the horizontal syncing is continuous, the vertical sync pulse is notched or serrated; another train of pulses called the equalizing pulses is added ahead of and after the vertical sync pulse.

The Vertical Retrace

Moves

From

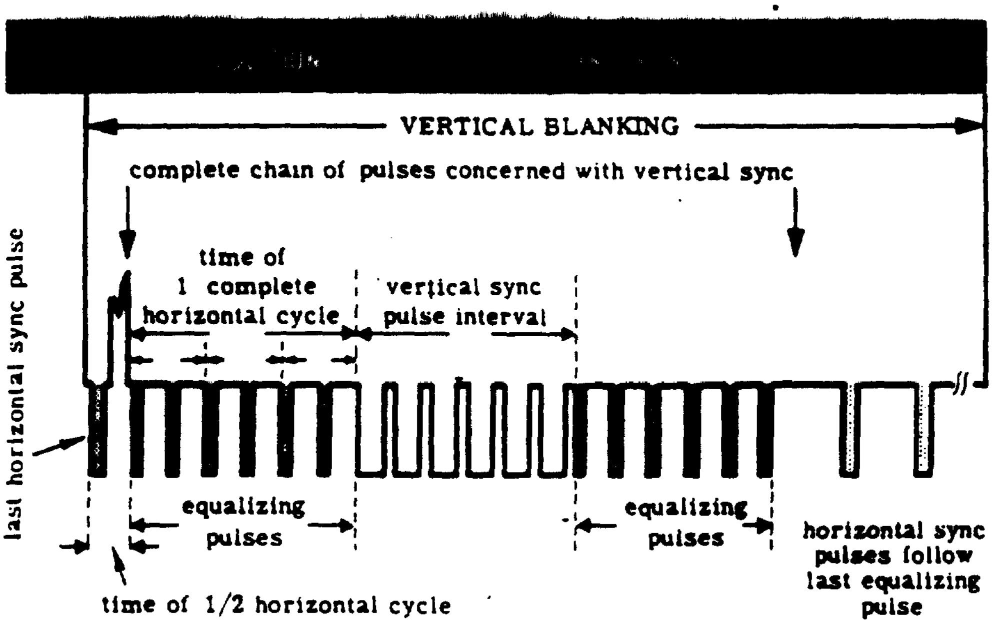


Side to Side As The Beam Climbs Upward

You will recall the statement that there are 262.5 horizontal lines in each field. The simplified presentation of the odd and even fields showed the odd lines numbered from 1 through 525 and the even lines numbered from 2 through 524. Obviously the vertical retrace period of each field must consume some of these lines. This happens, but it is not necessary to again present the organization of the lines in each field. We simply accept the fact that about 20 lines per field are inactive because of vertical blanking.

Completing the Vertical Sync Action (Equalizing Pulses)

The description of the vertical sync action is completed when we add the *equalizing pulses.* They appear as two trains of six pulses each in each field: one train timed to appear just before the vertical sync-pulse interval and one train immediately after. They have the same polarity as the vertical sync pulse, but are unlike the latter in that they are short duration pulses. They, too, are formed so that the interval between two adjacent pulses corresponds to a horizontal scanning cycle, thus providing the equivalent of three horizontal sync pulses immediately efore the vertical retrace appears, and three horizontal sync pulses immediately after the vertical sync pulse. In this way they keep the horizontal deflection generator on frequency during the period when the vertical deflection generator is being made ready for the reversal of the direction of the deflection current. This is the initiation of the vertical retrace.



Note these are the equalizing pulses for one field only - the odd line field

The "get ready" interval is required because each field contains a half-line. The instant of triggering of the vertical retrace action of the odd line and the even line fields differs by a half horizontal line. The last horizontal line in the odd field ends at the center of the bottom edge of the surface being scanned, completing the last horizontal line of the even field which ends at the right corner of the bottom edge. The equalizing pulses in each field take care of this time difference and trigger the vertical retrace of the successive fields at the proper moments so that correct interlace of the horizontal scanning lines takes place.

The Serrated Vertical Sync Pulse

When thinking about synchronizing the vertical deflecting system of the receiver and the camera tube, we should not lose sight of a similar need for synchronization in the horizontal deflecting system. The simplified version of the vertical retrace shows it as an instantaneous movement from the bottom edge to the top edge of the mosaic, screen, or target. Actually it does not retrace this way.

Popular or simplified version of the vertical sync pulse

Technical or actual version of the vertical sync pulse

THE VERTICAL SYNC PULSE IS NOTCHED SO AS TO CONTINUE HORIZONTAL SYNCING

The time interval between each two pulses is the same as between horizontal sync pulses 63.5 μsec.

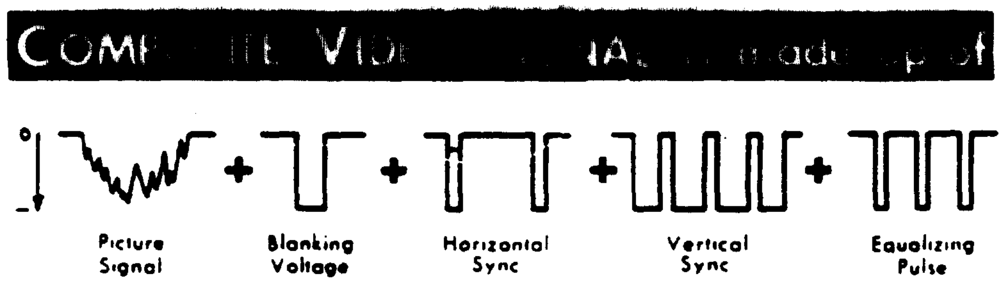
To maintain horizontal sync during the presence of the vertical sync pulse in each field, the pulse is notched or serrated. This reforms the single long pulse that we illustrated into six like pulses of comparatively long duration with short intervals of no sync voltage between. The serrations are positioned so that the time interval between the leading edges of each two adjacent notches is the same as between two adjacent horizontal sync pulses. In this way the horizontal deflection generator is subjected to three horizontal sync impulses during the time when the vertical sync pulse is active in each field.

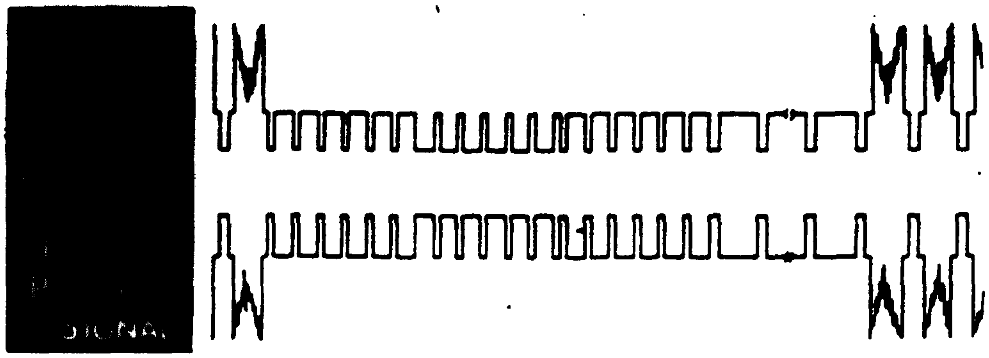
The vertical sync pulse on the vertical deflection generator is not impaired by the short intervals when the sync voltage falls to zero (the notches). Vertical syncing behaves as a constant amplitude pulse. As will be shown later in the course, the receiver system distinguishes between the horizontal and the vertical sync pulses due to the difference in duration and voltage intervals between these pulses. (You can see this difference for yourself if you compare the above notched vertical sync pulse with previous illustrations which show the horizontal sync pulses.)

Serrating the vertical sync pulse does not in any way change its relationship to the blanking pulse on which it rides as illustrated in the preceding drawing. Everything said before still applies.

The Composite Video Signal

The addition of the horizontal and vertical blanking pulses, the vertical sync pulses, and the two trains of equalizing pulses to the picture signal produces what is called the *composite video signal.* This is the signal output from the video amplifier at the transmitter, and is used to amplitude-modulate the picture carrier. Since the process of composite signal transmission is continuous as long as the transmitter is on the air, any single train of signals may represent a short period of transmission without regard to the field, or portion of the field, that is being transmitted, unless the contrary is specifically indicated. We should also mention that it is customary to symbolize the waveform of the picture content between horizontal blanking pulses by the use of jagged lines.



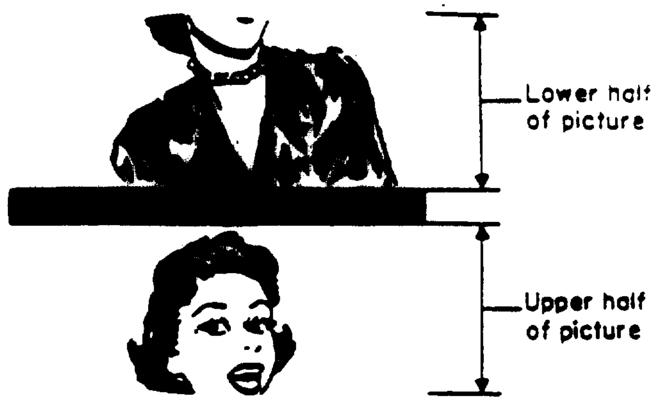


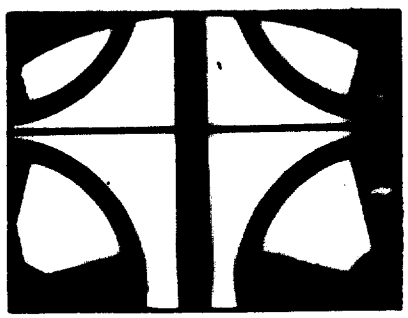
Another point which should be mentioned is the polarity of the composite video signal. Our discussion so far has been concerned with negative polarity signals although the illustration of the composite signal is more often one of positive polarity. The sync pulse peaks are the highest signal levels and the white content of the picture is the lowest signal level. However, the lowest peak signal level is not equal to the zero level of the signal used for modulation. The FCC and industry standards set the whitest signal at 5% to 10% higher than the camera's white output.

... receive synchronizing **pulses at the same time as the picture signals?**

A. These pulses occur in the periods between lines and fields when no picture information is being transmitted. In some receivers the vertical blanking interval can be seen by adjusting the vertical hold control until the picture begins to roll over. In this way the portion of the scanned area normally hidden by the mask can be made to appear in the picture area.

... result of a slight re-adjustment of the vertical hold control





Horizontal and Vertical Sync

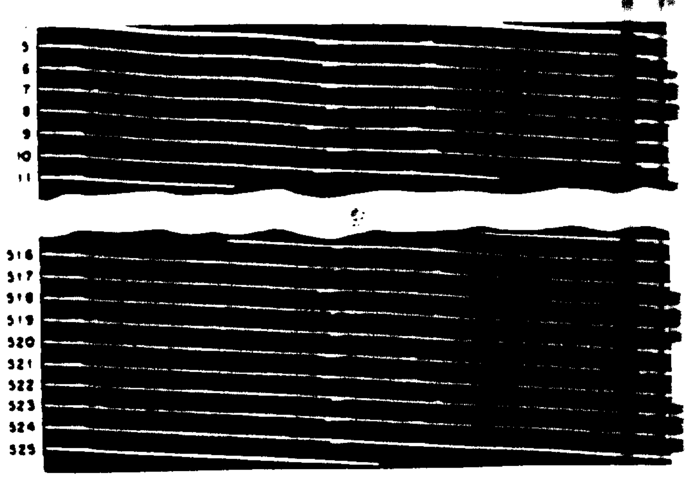
05763

195

THE TELEVISION WAVEFORM

14. What is meant by blanking?

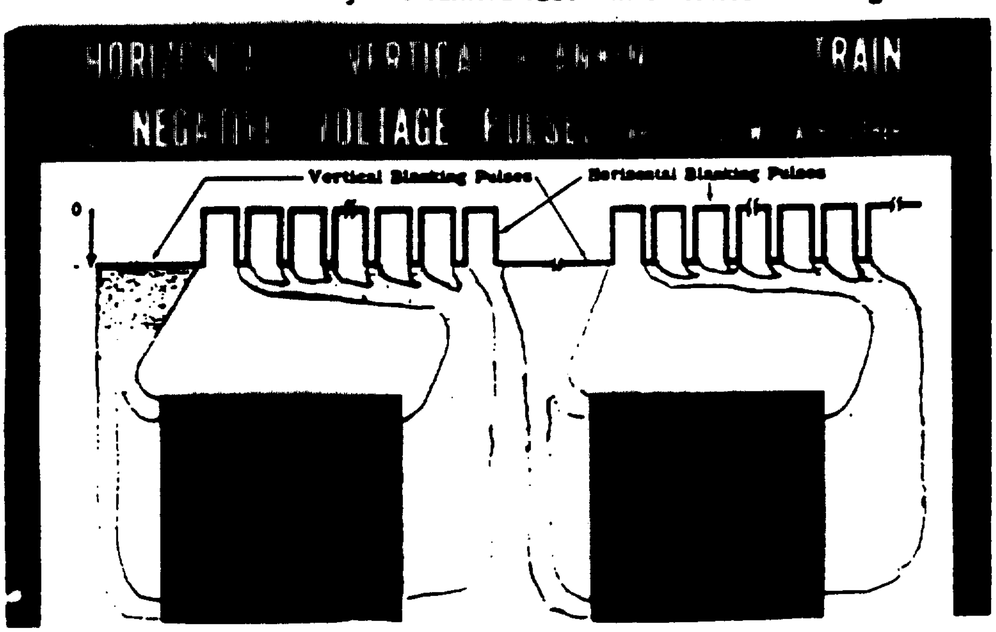
A. Blanking is the process of rendering the scanning beam inoperative so that it will not be seen during the retrace periods. Horizontal and vertical blanking pulses cut off the scanning beam as it is moved from right to left for each line, and as it travels from the bottom to the top of the picture after each field. These pulses are inserted in the composite video signal at the transmitting station.



Adding the Blanking Pulses to the Picture Signal

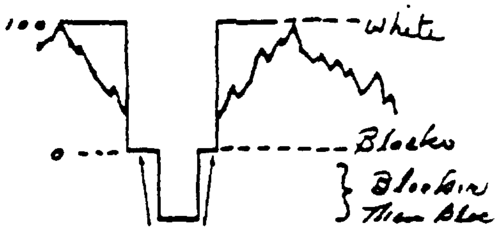
To display the picture on the monitor screen and eventually on the receiver tube screen without showing the horizontal and vertical retrace motions of the beam, horizontal and vertical blanking voltages must be added to the picture signal. These pulses must appear in the same time sequence as the horizontal and vertical retraces during scanning. To assure perfect timing, blanking voltages are supplied from the pulse generator through the blanking amplifier in the control room, the same source which supplied blanking voltages to the camera tube.

The blanking pulses are of negative polarity. Their amplitude varies between zero and a suitable peak value which exceeds the peak amplitude of the signal corresponding to black in the image. Also, they are of two different durations: the horizontal blanking pulses have a duration period that is only a small fraction of that of the vertical blanking pulses. The pulses are generated as a continuous train and follow each other in the same sequence that patterns the beam retrace intervals during scanning. Since there are many more horizontal than vertical retrace intervals in a field, there are many more horizontal than vertical blanking pulses in the train. In this regard we should clarify a point. Horizontal blanking in a field begins after the first 7 to perhaps 12 horizontal lines have been scanned, and ends when about 2 to 4 horizontal lines remain to be scanned. The reason for the delay in starting the horizontal blanking and for ending it before the field is completed is the vertical blanking pulse. Because of its time duration it starts before the beam is at the bottom of the camera tube mosaic (or target). That is when about 2 to 4 horizontal lines remain to be scanned in each field. It is active during the entire vertical retrace and remains active during the scanning of the first 7 to 12 lines of the next field. Starting early and ending late is insurance that the much slower vertical retrace will not be visible on the picture tube screen. We should emphasize that the action of the vertical blanking pulse during the period just described blanks the two groups of horizontal lines as well as the vertical retrace. Picture information is not delivered by the camera tube while vertical blanking is active.



P16

A. In a composite video signal, blanking level corresponds with zero signal level. Below this level, in what might be termed the "blacker-than-black" or negative direction, are the sync pulses; above this level, in the positive direction, the picture signals appear.



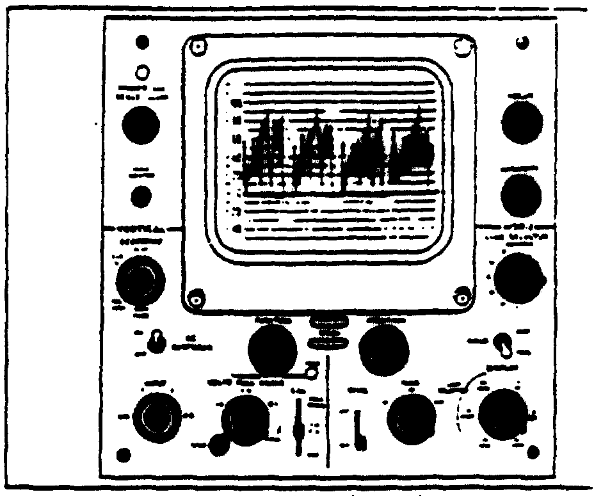
Pedistal is the flat portion of the blanking pulse.

05764

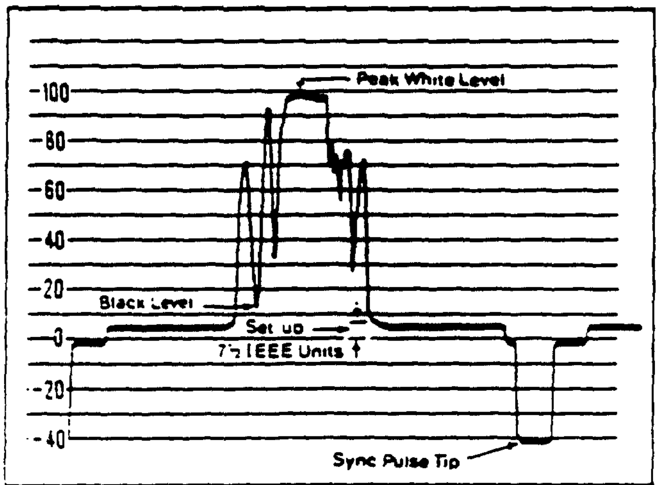
What method is used to adjust the signals to the proper levels?

A. The picture signals and the sync pulses can be displayed on an oscilloscope as video waveforms. An engraved graticule attached to the face of the oscilloscope has a scale divided into 140 units, with 100 units above zero (blanking level) for the picture signals, and the remaining 40 units below the zero line for the sync pulses. An oscilloscope used in this manner is known as a waveform monitor, and the graticule scale is specified in a standard of the Institute of Electrical and Electronic Engineers (IEEE).* It is customary to refer to video signal levels as so many IEEE units above or below blanking.

*Formerly Institute of Radio Engineers; now called Institute of Electrical and Electronic Engineers, 345 47th Street, New York, N.Y. 10017



Waveform Monitor
(Shown without sync pulses or setup.)



Waveform Graticule Scale with Single Trace